UNDERSTANDING

the Practical Application of

GENETICS

by
Mary Lou Kenworthy

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FORWARD

In the Autumn of 1997, Karen & I had the privilege of spending five days in the beautiful hill country Northwest of Atlanta, Georgia with Mary Lou Kenworthy. The sunny weather was a welcome change from the gray overcast skies of upstate New York, but the weather was not the reason for our southern sojourn. The time had come for our tri colored Basenji bitch to meet her arranged suitor, a pure for red, southern gentleman.

Another reason to soak in some Georgia sun was to bring home our first brindle Basenji. For ten years, we had owned and raised only Red & White and Tri colored Basenjis. At the shows and specialties, we would look at the brindles and think, maybe someday... Now the opportunity wagged its tail.

Also, I could now spend an extended period of time querying Mary Lou about her thirty years of accumulated knowledge of Basenji history, pedigrees and genetics. I packed the pedigrees, all my genetics books, a three ring note-book with a ream of blank paper, and a list of questions. The purchase of our first brindle meant a responsibility to learn the consequences of introducing the brindle gene into our breeding program. It was at this time that Mary Lou shared with me her rough draft for this book.

This book is designed to get the Basenji fancy to look at the importance of coat color genetics in todays Basenji gene pool. The intent was to keep the subject matter simple by using a Basenji model covered with successive layers of paint to illustrate recessive colors and patterns. I feel that her Basenji model, with layers of paint, is a good visual tool for breeders who lack knowledge of color genetics symbolism and its application to a breeding program. If such a model works 99 to 99.5% of the time, breeders can use it to plan matings to produce the desired colors with a good degree of certainty. Mating formulas are also introduced to stimulate further investigation of coat color genetics.

Mary Lou presents her modified theory of the A & E series and suggests further modification may be necessary as we continue to unravel the finer points of coat color inheritance. Her theme that "The World Is Our Classroom" implies we must wake up and notice what we are producing and keep asking why until we find answers.

Mary Lou is a natural resource of information on the breed. Her theory and recommendations are based on thirty years of her own breeding, knowledge of color inheritance in other breeds, and notations made on other Basenji litters with "surprising results". Mary Lou points out that only six other AKC breeds recognize and produce both Tan and Blacks (or Tris) and Brindles. Having both these color/patterns complicates breeding for the four recognized standard colors in Basenjis.

Mary Lou serves an important function for our breed, which at times generates emotional reactions. Mary Lou is a great provocateur. She provokes discussion, or provides the needed stimulus to get others to think deeply about the welfare of the breed. Undoubtably this book will get many to think deeply about the inheritance of coat color and patterns. She will be the first to admit that she doesn't have all the answers, but she feels that Little's book, *The Inheritance of Coat Color in Dogs* and Willis' *Genetics of the Dog*, do not explain several coat colors and patterns found in the Basenji, such as the "Fula black".

It has become evident that there is a need to educate Basenji breeders about Basenji coat color inheritance. As articles and letters in the BCOA Bulletins over the past year have shown, there are many misconceptions of Basenji coat color inheritance and a vast range of opinions on the subject. Whether you want to breed just one or two pure colors or all four, here is your launching platform. Mary Lou Kenworthy's *Understanding the Practical Application of Genetics* will be a classic breeders handbook well into the Twenty First Century!

Everett C. Pashley
Kalever Basenjis
Cooperstown, N.Y.
March 20, 1998

ACKNOWLEDGMENTS

Many thanks go to Jo Ann Fimlaid for urging me to "write an article explaining how color is inherited". I kept telling her it would take a book. Well, here it is.

The help of many others was greatly appreciated. Sally Ann Smith had a very busy time with her red pen changing grammar, correcting spelling, etc. Many thanks for proofreading!

The mathematical brain of Everett Pashley came in very handy in double checking the accuracy of the questions and answers. He patiently worked them all out using more symbols and formulas than you would care to know about. The last I heard, he was still working on the Brain-Twister!

The book also needed to be tested on someone who was not interested in the genetic symbols to see if it was understandable without prior knowledge of them. Robyn Dubbert was kind enough to act as guinea pig for this.

My biggest snag came when I found out that my computer was not compatible with anything on this planet and for future writing I will have to learn a whole new 'language'. The writing had already taken far too long because it was hard for me to find the time to work on it. I felt the fastest way to get it out was to have someone type it over in usable form. For this I am very grateful to Deborah Mizzoni who took a seemingly insurmountable task and made it look like child's play.

Thanks to Carmella Troisi-Hoerr for her excellent layout, once she got the book in a form she could work with, and for technical advice and assistance in the publication.

And last, but far from least, I owe my undying gratitude to all my four legged teachers. It is they that made this book possible.

March 1998

INTRODUCTION

The teacher's voice droned incessantly in the background of my thoughts as I thumbed idly through the text book. Suddenly something caught my eye, something about crossing red and white peas. I began to read. Finally something worthwhile; perhaps adults were right and school can teach you things that you need to know in life.

Luckily, that chapter about a monk of long ago and far away was the assignment for the next day. Boy was I prepared, read it three times, my all time record for doing homework. There were always more important things upon which to focus my attention, like horses, dogs, etc., but this guy Mendel was on to something and I wanted to know more.

My enthusiasm in school waned as we went on to other things and nothing ever peaked my interest again like the introduction to genetics.

It was many years later before the opportunity came my way to study genetics again from books. In the meanwhile, I was observing the workings of inheritance all around me.

All too few people can say that their childhood dreams and ambitions have come to pass. For better or worse, I've followed my dreams. From an early age, I knew that I wanted to raise animals, mainly horses and dogs, and that I wanted to write. The actual writing could wait until I was old and gray but I would gather information in the meantime. I hated the actual act of writing with a pen or pencil and always 'knew' something would come along to deliver me from this. I took typing in high school and then sat back to await the invention of data processing.

The realization that not only could I breed animals, but that I could change and improve that which I was breeding, drove me into every book on genetics that I could find. The first thing I discovered was how little I knew about the subject. The second thing I learned was how little the 'experts' knew as I quickly ran out of reading resources. Most texts written since that time refer back to, and rely on, the original studies and test breedings done at Bar Harbor in the '50s. These studies were of particular interest to me as I was involved with two of the five purebred dog breeds that the studies were based on.

Today we are looking at things like organic chemistry, DNA studies and microbiology. Most of what will profit animal breeders from these studies is still far in the future. There is a huge gap between their theory and discoveries and our practice. When trying to pick the brain of a molecular biologist, I found that what I wanted to know was the time and all he could tell me was how the watch was made.

Chapter 1

THE WORLD IS A CLASS ROOM

Welcome to 'Genetics 101'! We are about to embark on a journey down the long and winding road to 'Understanding Genetics'.

Now, don't panic, it's really not that bad. We're not going to get into complicated formulas. Think of this not as a science or math class but more of an art class.

When we reach the summit of 'Understanding', we will be able to view the broad valley of 'Application'. From there, there is no boundary to where our wisdom may take us. Think of this experience as the beginning of an adventurous journey that could last a lifetime. So, sit back, relax, read, observe and think, but most of all, enjoy the trip.

When my 'dog' interest turned to the Basenji breed in the early 1960's, I had no idea of the education I would need or get. Having bred Shetland Sheepdogs in the past, I had some insight into the color inheritance of the Basenji. In Shelties the sable was dominant to the tri-color and the blue merle was a tri- with a dilution factor. In the Basenjis, the red was dominant to the tri-color and there was no merle. Simple! Well, not for long.

At about the time I was phasing *out* of Shelties, a 'new' color, black (no tan markings) and white, appeared in that breed. Then, at about the time I was phasing *into* Basenjis, a 'new' color, black (with no tan markings) and white appeared. I was doomed to deal with this color. It did not appear to be a problem as the Basenji standard allowed for black and white Basenjis. However, it didn't take Basenji breeders long to discover that black was inherited in **two** different ways.

There was a dominantly inherited black which was introduced by Basenjis from a different part of Africa from where the first reds and tris originated. These dogs, from Liberia, were born black and remained black throughout their lives except for the graying of old age. To produce this black, at least one of the parents had to be black.

There was also a recessively inherited black on which tan hairs could appear to varying degrees as the dog aged. To produce this black, genes for it had to

come from both parents. The destiny of my early Basenji litters seemed to be to teach me of all the variations of colors that I did not want.

I had acquired a red and white bitch from a lady who was getting out of Basenjis because of a terrible kidney disease that was behind the lines of this bitch. The bitch herself was healthy so I took the chance. Her pedigree contained a combination of two of the then major blood lines in the east. I had also acquired a red and white male from a third major eastern line combined with some mid-west breeding. Phynotypically they were compatible, so I bred them together. I was expecting red and white puppies and possibly some tri-colors.

Surprise! She had four black and white and one red and white. "Sometimes you can't see the tan when they are wet" I was told. "It will show up when they are a few days older." I kept rubbing with the towel, but no tan markings could be seen. They didn't appear in a few days either. I had four recessive black puppies. The red was just a normal red and white. Not only did I have four black puppies, but I had two distinctly different gene combinations on those black puppies. The black bitch went to a home near me, but at about one year of age she got out and was killed by a car. At the time of her death, her black was still all black with no sign of tan hairs. One black male from this litter went to live with some friends and, at about two years of age, he developed a few tan hairs under his tail but you had to look closely to see them. The only other color change was graying with age. He lived to be 14 years old.

The other two blacks were a different story. At about seven weeks, tan hairs began to appear at their extremities. The tan hairs spread through the black, up their legs and through their heads. The tan color did not replace the black but intermingled with it, making it a very muddy and unpleasant color. The tan continued to spread through the body until the only clear black left was over the back in the saddle area. What I had was two extremes of the effects of modifiers or other recessive genes on what Basenji breeders refer to as the 'Fula black'. From what I've seen over the years, there can be any variation of the amount of color bleeding between these two examples.

By four months of age, the latter two Basenjis were so ugly I could not give them away and eventually had them euthanized. From this experience, I learned that the best way to cope with such problems is to not breed them in the first place. Correct color became one more criterion for my breeding animals.

So, just what is a 'Fula black' genetically? It takes a pair of genes for recessive black, one coming from each parent. This is the simplified version which will suffice for now. We will look at the whole picture later in this study. This color is rarely seen today in the USA, but the genetic make-up is still present in our gene pool and can be seen in our occasional 'Fula tris'. We will get into a more detailed explanation of 'Fula black' and 'Fula tri' at a more appropriate time.

At about the same time as my introduction to the recessive blacks, I had an ever stranger litter. It too somehow involved the 'Fula black' genes as the sire of

this litter was also a red dog carrying the 'Fula black' as a recessive. The dam was a red and white that probably was pure-for-red; she had had only reds in previous litters. However, she was a slightly different shade of red from anything else I have seen. Perhaps she was what I have heard older breeders refer to as 'paper bag brown' although her coat was not dull and was very short.

In the resulting litter were normal reds and what appeared to be blacks until they started to dry. Then you could see that the top of the head (where a new coat first appears) was a bright, dark red. I called them my 'red-headed woodpecker' puppies. As they aged, the black hairs began to fall out, just like the guard hairs of normal reds, except that the clearing was not complete. The changing color followed the same pattern as the first mentioned litter. The red began replacing the black at the extremities and head first and then moved on toward the back. I grew out one of these puppies to see how it would turn out. At the age of seven weeks, the colors were intermingled and this puppy looked like one of the first mentioned litter turned inside-out. She was predominantly red with a black shadowing over the back in a blanket pattern and black shadowing on the back of the neck. The rest of her body appeared red but on close inspection had black hair sparsely intermingled. By three months she appeared to be red with a saddle of black and red hairs. The saddle cleared out over the next few months and at a year and a half she had only a few black hairs scattered evenly throughout her coat. She was never bred.

These two examples show the presence of unwanted colors in the Basenji gene pool. They are caused by either the saddling gene or the combination of modifiers that create the color combinations in German Shepherd Dogs. Shepherds are born black and turn to various adult colors in the same pattern as these Basenjis changed color. We will cover how and where these unwanted genes crept into our gene pool in a later chapter. But in order to understand how this happens, you need to know a little about the mechanisms of inheritance covered in the next chapter.

SOME BASICS

Let us start at the beginning with the cell where all the genetic material is stored. In each cell is a series of chromosomes. Each species has a specific number of chromosomes. For example, humans have 46, horses have 64, cats 38 and dogs 78. Chromosomes come in pairs, one of each pair having been inherited from each parent. Chromosomes are usually counted in pairs so therefore dogs are considered to have 39 pairs of chromosomes.

A quick review of **meiosis** reminds us of what happens when genetic material is passed from one generation to the next. The reproductive cells divide in half so that each has only a single chromosome from each pair. When united with the reproductive cell from the other parent, which also contains a set of single chromosomes, the new life has its 39 pairs.

Although we know that the genes in a chromosome are complicated chemical compounds designed by DNA, it will be easier for us to visualize them as strings of beads that are grouped together in a specific order. Picture the chromosomes as double strands of hundreds of beads each bead always in the same order as its partner gene on the other chromosome strand. Each gene has its own special location, or **locus**, on the chromosome as well as its own special job of influencing a particular part of the dog's makeup. This gene, however, does not work alone but is influenced to some degree by its partner gene, or **allele**, as well as by other genes that affect the same trait. Genes are not inherited individually but in groups, chromosomes. Therefore, all traits influenced by the genes of the same chromosome are genetically linked. The closer that they are located to each other on the chromosome, the closer they are linked. The

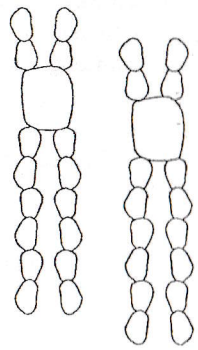

Figure 1 - It will be easier to understand if you imagine that a chromosome looks like this.

genes in the same chromosome tend to remain together. Therefore, all the factors influenced by this group of genes are inherited as a unit.

As we will be discussing the genes associated with the color of our model dog, the important thing to remember is that genes always act in pairs and that a gene's partner is its allele. This means that these genes appear at the same locus of corresponding chromosomes and influence the same factor of the dog. In the gene pool of a specific breed, there can be many different genes that belong to the same allelic series, but only two of these genes can be present at the same time in any one dog. There are always two genes at any given locus, even if they show no effect on the **phenotype**, or how the dog looks.

The Basenji will be our model dog for this study, so let's take a look at the blueprint for what we wish to breed. Concerning color, the Basenji Standard (AKC 1990) says, "Chestnut red; pure black; tricolor (pure black and chestnut red); or brindle (black stripes on a background of chestnut red); all with white feet, chest and tail tip. White legs, blaze and collar are optional. The amount of white should never predominate over primary color. Color and markings should be rich, clear and well defined, with a distinct line of demarcation between the black and red of tricolors and the stripes on brindles."

As white on Basenjis is a marking and not a color, we will not deal with it in our discussion of color inheritance but will give it a chapter of its own later in the book. The four recognized and desired colors are red, black, black and tan (which is a specific pattern) and brindle (also a pattern).

Researchers of nearly half a century ago such as Scott, Fuller, Little, Whitney, Willis, Pfaffenberger, etc., who conducted breeding experiments with various breeds and cross-breeds, established some basic rules of color inheritance based on Mendelian theory for many of our breeds. But back in the 'Bar Harbor' days, the Basenji breed was in its infancy in this country with only two colors being known at the time. One, that we call red, is really the sable gene of the A series, a^y, which was the Mendelian dominant to the other color, tri, a Mendelian recessive to red. "Life was, oh, so simple then."

Later imports from England and different parts of Africa changed all that by bringing in recessive genes that caused bleeding of our color patterns and dominant genes from other color series that affected our whole color inheritance. There has been no formal color test breeding done since these changes so the only written references we have are based on the early breedings of two colors, red and tri.

We will have to use our detective skills and look at the Basenji population around us, as well as what we can learn from other breeds, to determine what is happening now. The world is our class room, so let's use it.

We will try to stay away from too many symbols for color as they tend to confuse and scare people away.

Those of you who are already familiar with the work of early geneticists may have noticed that not all of them agree upon what belongs in each series. I have

some of my own ideas based upon experience with what works. However, I will try to use the same symbols that you are used to seeing wherever possible to denote the alleles, even if I view them differently.

The three basic allelic series involved in giving Basenjis their color are the "A", "E" and "B" series. They are so named because of the locus (on the chromosome) where they are found.

We will try to use symbols as little as possible, but the use of some will help make things clearer. A capital letter is used to depict the most dominant gene in its series. The lower case letters depict the recessive genes in the series and the superscript letters are used to differentiate between the alleles.

In the "A" or Agouti series, we have, at least, the following alleles at the "A" locus:

A^s (Little) a pattern factor resulting from the competition between a tendency to allow the spread of dark pigment and an opposing tendency expressed by other alleles. All other researchers use —
A dominant black.
a^y which is sable to the Collie and Sheltie folks and red to the Basenji people.
a^t which is tri-color to the aforementioned and bi-color to breeds without white, or, more correctly should be called Tan-Point Pattern as Little suggest.
a^w (Little) or a^g (other researchers) agouti (wolf gray).
a^s is the saddle marking (black over the back)
a^- author's representation of what is known in Basenjis as Fula black/tri and the bi-black of Shelties.

In the "E" or Extension series, we have:

E extension permits black (of the B series) to show on all colored areas of the coat (no black mask)
E^m permits black mask
e^{br} brindle or partial extension (striped patterns)
e restriction (of black pigment allowing the recessive tan/yellow to be expressed)

In the "B" series, we have:

B is the dominant gene at this locus and it causes the dark pigment at any location to be black
b is the recessive allele which produces liver, chocolate, brown, etc., same gene called by different names in different breeds. (This gene oxidizes, literally rusts, black to brown.)

There are other series that have been studied such as the albino locus, the depth of pigment locus, or the ones that cause merling, graying, spotting, ticking, etc. We will not confuse the present study with these at this time.

Chapter 3

VISUALIZING BASENJI COLOR RANKING

In the previous chapter, we reviewed the desired Basenji colors as described in the breed standard. Next we will look at how they relate to each other when we have all the proper color genes in the dogs we are breeding.

Imagine taking a Basenji statue and dipping it into tan paint. When that dries, you dip it in black paint. Think of this as recessive black paint because next we are going to cover it up by dipping our statue in red paint. Next, we are going to take a brush and paint black stripes on our red Basenji. When they dry, we are going to dip this statue into black paint again. Think of this as dominant black because it covers up everything else.

If we were going to add white markings, we would do that last because the white paint would cover up the effects of the color genes or paint that was under it on that part of the dog. However, white markings will be covered in its own chapter.

So now we have a dog painted in layers that signify the phenotypes of the colors. If we have a dog that carries dominant black, he will appear to be a black dog regardless of what the other colors may lie beneath the surface.

If we strip away the dominant black very carefully, we now have a brindle. This works on the statue, but what about in real life? Let's look at what the dominant black in the Basenji really is.

First, we have to have the proper genes from the "B" series to have this color at all. You will remember from Chapter 2 that the "B" series consisted of B which causes dark pigment at any location to be black. Also, there was b which

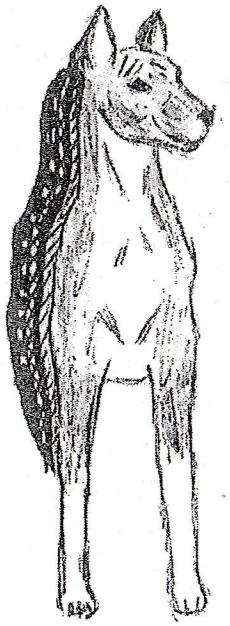

Figure 2 - Painted Layers on a Basenji

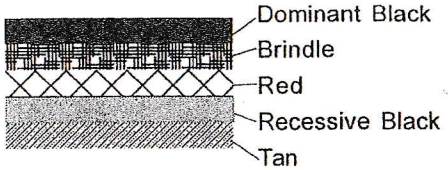

Figure 3 - Visualize the colors in this order. Starting from the bottom, each color will be covered up if genes for the succeeding colors are present.

caused this black to oxidize and change to liver. We do not wish to have the b in our Basenji color makeup so, since all genes are in pairs, the desired combination at the "B" locus is BB. However, having this alone does not make black. The BB is present in reds, tris and brindles also.

In order to have black, we must also have the E of the Extension Series which permits the black of "B" locus to express itself. It takes only one E gene to permit black as this is the most dominant allele of the "E" series. If an individual should possess EE at this locus, he would have to pass on an E to all offspring and would produce nothing but black puppies. It would probably be easiest to understand if I said that the black was dominant to the red and tri but that would be incorrect. A gene is said to be dominant only at its own locus and to an allele. Red and tri are at a different locus from black, so we must say that black is **epistatic** to red and tri. That means that black, E, will express itself despite the presence of the non-allelic genes for red a^y and tri a^t.

Now, next is the brindle. In order for the brindle pattern gene to express itself, we must eliminate the dominant black E gene from our dog. When the brindle e^{br} gene is paired with the E gene, the individual is black but will carry brindle as a recessive. In order for the individual to be brindle, the E gene must be replaced by either another e^{br} or an e. If the genes at the "E" locus are both e^{br} then everything that this individual produces will be striped. If the genes at the "B" locus are BB, the stripes will be black. If our individual is $e^{br}e$ at the "E" locus, he will be capable of producing stripes on whatever is contributed from the "A" locus plus the same color(s) without stripes.

Let's strip off the stripes and look at what this individual carries at the "A" locus. If this gene is a^y, we will see red. With a^y and e^{br} having proper mates and BB being present, we can have brindle, black stripes on some shade of red/tan. Here, we run into two kinds of re. One we call "pure-for-red" which means simply that both genes at the "A" locus are a^y. An a^ya^y individual can throw only red from the "A" locus, so therefore his offspring will be red unless something from the "E" series causes it to be black or brindle. In this case it will still carry a gene for red. The other kind of red is a^ya^t. This red has one gene of the pair for red and one gene for tri and is referred to as tri-factored red. If an individual of this makeup throws the a^t gene and another a^t gene is contributed by the other parent, the resulting offspring will be tri-colored unless there is also an E present to make it black or an e^{br} which could place stripes on the tri. In the latter case, the stripes would be visible only where they fell on the tan parts of the body.

The word "**trindle**" has been used by some to describe this unaccepted color of tri-brindle.

Now we are going to carefully remove the red paint from our statue so that we will be down to the recessive black. Also we are going to very carefully remove the black from parts of the statue, namely, cheeks, pips (the dots above the eyes), shields (the markings on each side of the chest), vent, breeching, underside of tail, feet and part way up the legs. Remember, we are working without any white at this point. With the white, this would be our tri-color, but as it is this is a typical black and tan (or bi-color) pattern. This is the bottom color or the most recessive as the other colors mask it if they are present. In breeding, this color breeds true; tri to tri will give you nothing but tris.

Let's start at the bottom of the scale and go up once more showing the results of breedings that produced acceptable colors only.

Tri + *tri* = tri

Tri + *tri-factored red* = tri-factored reds & tris

Tri + *pure-for-red* = all tri-factored reds

Pure-for-red + *tri-factored red* = pure-for-reds & tri-factored reds

Tri-factored red + *tri-factored red* = tri-factored reds, pure-for-reds, & tris

Pure-for-red + *pure-for-red* = pure-for-reds

Pure-for-red + *brindle* = pure-for-reds & brindles

Brindle + *brindle* = brindles & pure-for-reds

Black + *black* = black & whatever combinations are present on the "A" locus

Black + *pure-for-red* = blacks & reds (the kind of red will be determined by the genes the black parent carries at the "A" locus)

Black + *tri-factored red* = blacks & reds & if a tri- gene is carried by the black parent, there can also be tris

Black + *tri* = blacks & if the black parent carries a tri gene, there can be tris; if the black parent also carries a red gene, there can be reds also; if the black parent carries two genes for red, there can be reds but no tris; if the black parent carries two genes for tris there can be tris but no reds.

Note: The brindles referred to above are not pure for brindle. They carry two red genes at their "A" locus. The blacks are not pure for black, nor do they carry the brindle gene. (The other allele for black & brindle is "e".)

"But why should we worry so much about this?" asked Bobby. "After all, it's just color! Shouldn't we be more concerned about more important things like conformation, health and temperament?"

Of course. Every aspect must be considered in breeding. Color is just one feature. As we continue to learn, you will find it may be more important than you think. Besides being genetically linked to other factors, color is the most obvious feature that can be seen and understood by everyone. Therefore, it should be the easiest factor to control. If one does not comprehend the genetics of something so easy to see as color, can they be expected to intelligently control the other qualities of what they are producing? What people see is the outside of your dog. This gives them their first impression of you as a breeder. What kind of message will you send by showing a color that is not accepted by the breed standard?

Chapter 4

SOME OTHER COLORS

Before we get into the unwanted colors and how to avoid them, we must look deeper into one of our accepted colors and understand it for what it is. Tri color in Basenjis has been looked at as being a single gene when it is really more. Usually both the black and tan are inherited together and appear to be a unit that follows the Mendelian theory for a recessive. This is the way that most early researchers have treated the inheritance of this color pattern. They put it in the "A" series as a^t where it works very well in most cases. However, Paramoure felt that it really belonged in another series, although her reasons were not clear. It is my feeling that she was "seeing" the effect of this color's true inheritance and this was causing her to think it belonged in a different series.

We are going to treat the black and the tan as separate entities and look at them individually. The black is just as we have been treating the combination, a recessive, the most recessive color of the "A" series. The tan color is probably caused by the e of the "E" series and is expressed as a pattern which is incompletely dominant. It takes a double dose of the tan point genes for the full expression of the tan pattern on bi-colored (tri) Basenjis. Are you with me so far? Mary has a question.

"What about the 'Fula tris'?"

This is a good time to tackle that elusive, never mentioned in genetics, phenomenon, the 'Fula' factor. Basenji breeders dubbed this color pattern 'Fula' because it first appeared when the descendants of 'Fula' were mated together.

"Who is 'Fula'?", Jim asked.

'Fula of the Congo' was the bitch that Veronica Tudor-Williams brought from the African jungle to England in 1959 when 'new blood' was needed to further develop the Basenji breed. Top Basenjis the world over are descended many times from 'Fula'. Stanley Dangerfield, a world famous breeder and author, probably described her best. In 1968 in the 'Daily Express' he said of 'Fula', "No dog of any breed has ever made a more dramatic contribution to progress."

However, no new additions are ever made without bringing problems as well as attributes. The 'Fula' black is the recessive black described in the first litter

example in Chapter 1. The recessive black of correct tris and of 'Fula' tris and 'Fula' blacks is the same. It is at the locus for the tan markings where the difference occurs. The 'Fula' tri is a tri color with incomplete tan markings. The tan will appear to be restricted, that is, not covering quite as much area on the cheeks and muzzle as on a correct tri. The pips may be smaller or absent. There may be a whole or partial vertical black 'bar' across the tan cheek, such as seen on Dobermans and Rottweilers. As a 'Fula' tri matures, the tan usually bleeds into the black of the legs and the head just as the tan begins to appear on a 'Fula' black.

What is this gene? It isn't a gene that causes this restriction and bleeding but the **absence** of a needed gene that creates the 'Fula' factor. One or both of the incompletely dominant genes for the tan pattern has been lost. If only one is absent and its allele for tan pattern is present, the result is what has just been described as a 'Fula' tri. If both tan pattern genes are absent, this creates a 'Fula' black.

Since there cannot be a hole in the chromosome where the gene or genes for tan pattern are missing, another gene has to come in to take its place. Let us invent a new series and call it the "P" series (Pattern). It is my theory that the tan pattern gene locus is located very close to the locus for recessive black ("A" series) or, at least directly affects it. It is quite probable that the genes that cause saddle and blanket patterns in hounds may actually belong in this "P" series. The Agouti may belong here also instead of in the "A" series as it could be what is causing shaded reds in tri-factored reds and 'Fula' tri-factored reds. Any of these genes could replace the bi-color pattern gene, which we will call Pattern — tan points P^{tp}. When this happens it causes the different degrees of bleeding of the black and tan colors. The amount and location of bleeding is determined by which gene replaces the P^{tp} gene.

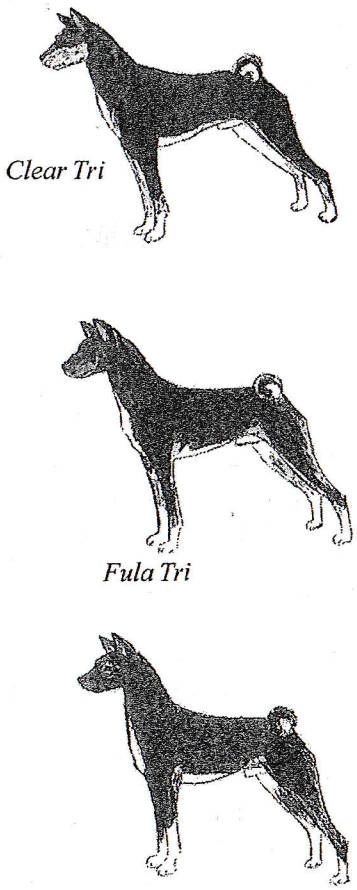

Figure 4 - This is how a Fula Tri appears in comparison to a regular tri. The Fula black has no tan markings per se, but tan hairs will intermingle through the black color.

There must be more than one other allele because the reaction of the 'Fula' colors is not always the same. Some dogs may develop a lot of tan intermingling with the black and other dogs develop only a little. Also, we should note here that head and body markings and patterns are inherited independently of each other although they are closely linked and usually compliment each other.

Bleeding of the black and tan occurs in some lines of Basenjis that do not have 'Fula' behind them. This bleeding is generally seen only on the back legs where the tan hairs sparsely intermingle with the black around the lower thigh. The genetics in this case are probably, at least partly, different as the tan does not bleed higher into the body. The tris in these lines all have the same amount of intermingled color in the same place and it doesn't vary as with the 'Fulas'. I don't have any personal experience with these lines so won't try to elaborate further except to say that the sharp line of demarcation so greatly desired seems to have broken down in this lower thigh area. The head markings of these dogs are unaffected and are like clear tris with a good line of demarcation and full expression of tan. The 'Fula' tris will have varying degrees of tan expression on the head. This tan will change with age and bleed into the black around the eyes.

The best way to avoid the bleeding 'Fula' colors is to preserve the correct tan markings, $P^{tp}P^{tp}$, which must be carried by all our breeding stock.

The dominant black genes BB must be carried by your breeding stock in order to avoid bb or liver color.

At the "D" locus of the chromosome, we have the alleles D, which causes intense pigmentation, and d which causes dilution of dark pigment when both genes at this locus are d. In Basenjis we wish to avoid the dilution factor so must keep our animals DD. This is what all of our Basenjis of the correct colors carry at the "D" locus. If they carry a d they are in danger of producing a dilution if this gene meets up with another d. The color that is diluted depends upon what color genes are carried at the other loci. For example, the a^y dilutes to cream and the black and tri dilute to blue.

While this dilution gene works well in some breeds, it can be semi-lethal in others. In Dobermans, it appears to cause, or at least be linked to, coat and skin problems, even when only one gene of the pair is a dilution gene. The presence of dd in the genetic makeup dilutes black to blue. In the case of the faun, or isabella, Dobermans, there are two changes involved. The first is the presence of the genes bb which oxidize the black to liver (red) and second is the presence of the genes dd which dilute the liver (red) to faun. Although these colors are allowed by today's American standard, some Doberman breeder choose to avoid the dilution genes in their breeding programs. Early German breeders considered the isabella color a severe fault and even, at times, a disqualification. These dogs showed general loss of pigmentation, light eyes and noses, which was believed to accompany or indicate weakness and deterioration of body and temperament. Dobes that I was personally familiar with that carried dilution genes always had skin and coat problems and allergies.

There may have been some genes for the recessives of the "C" series (Complete Albinoism) in our gene pool which would account for the "cream" Basenjis with little skin pigment. In most cases Basenjis are CC at this locus, or homozygous for full pigmentation.

The 'mask' is another undesirable trait that occasionally shows up in some lines of Basenjis. While most noticeable in reds, it also muddies the tan in the faces of tris and, if allowed to unite with the brindle gene, will muddy the base color of their muzzles as well. Some who have it advocate it and try to pass it off as an advantage by calling it mascara, a term unfortunately not defined in Spira's "Canine Terminology." In my experience, mascara is used to define the dark (black) pigment of the **skin** around the eyes and lips, not black hair scattered through this general area. The desired dark pigment of the skin comes from the "B" series, not the "E" series responsible for the masks E^m. At any rate, the black hairs of the mask go against the standard which calls for 'rich, **clear**, and well defined". We'll take a harder look at the mask in a later chapter.

In order to avoid 'tri-brindles', there should be no genes for the recessive black in your brindle breeding stock. That includes the reds used also; they should be pure-for-red. Also, it would be wise to **not** have the dominant black gene expressor E in your brindle stock. One reason is that you will not be able to tell if the blacks are carrying brindle or not without test breeding. But, the main reason is that the large majority of blacks in the Basenji gene pool carry the 'Fula factor' as a recessive and this should be avoided.

The only time you can tell when an animal is carrying the 'Fula factor' is when you have a 'Fula' tri. This is the only stage at which it can be seen. To eliminate it, breed the 'Fula' tri to a clear tri and retain only the correct clear tris for breeding. Be advised that to be sure which is which may not be easy. There may be a fine line in the amount of tan between the two kinds as a 'Fula' tri's color may not show signs of bleeding until it is well past a year. If you have reds, blacks or brindles carrying the 'Fula' factor, you cannot tell until it comes out in breeding. To avoid confusion in the future, it is best to clear your lines of this color hazard. Refer to the color breedings listed in Chapter 3 to avoid problems.

As discussed previously, the way to eliminate the 'Fula factor' is by retaining two alleles for the tan pattern in bi-colors (tri colors in the case of Basenjis). As they must be present at all times in all our breeding stock, they must be carried not only by the tris but also by the reds, blacks and brindles if all four colors are to coexist in the breed gene pool.

The tan points are epistatic to the recessive black of the "A" series. That is, they are expressed in its presence. The tan points act **hypostatically** to the E and the e^{br} of the "E" series and to the a^y of the "A" series. That is, they are hidden by these other genes except that, in the latter two cases, evidence of their presence can be seen by the discerning eye.

The tan points P^{tp} are apparent, upon close inspection, in reds and brindles that do **not** carry the recessive black. This supports my reasoning that the black and the tan should be treated as separate, but linked, genes.

The black mask in Basenjis has me puzzled as I do not have enough information about its inheritance. It does not appear heavy as in other breeds and varies not only in intensity but in length of time it is visible.

Most red Basenjis are born with a spattering of black guard hairs throughout the body. The black hairs are concentrated most heavily on the face and dorsal areas and are replaced by clear red hairs as the puppies age. The black hairs are more pronounced and retained longer in tri-factored puppies than they are in pure-for-red puppies. The black at the base of the tail may show for the life of the dog in tri-factored reds.

The black hairs on the faces of red puppies will disappear earlier on those that are good clear reds, usually earlier than three weeks of age. When the black persists on the face longer, it is considered a mask. Some masks may fade at several months or years and some never completely go away.

The genetics of this persistence mask are not clear, but it can appear from two apparently unmasked parents. This mask can also be seen on the tri-colors. It gives a smutty dirty look to the tan on the muzzle.

The Basenji mask does not act like the E^m of the "E" series which appears black for the life of the dog. If the masking in Basenjis is caused by this gene, it is acted upon by modifiers that are turned off and on by other 'timing' genes kicking in and out at different stages of development. It is quite likely that doubling up on this masking would intensify it, producing a really black mask. Hopefully this will never happen as it is a trait that should be avoided.

Because the mask destroys the clear colors that the standard calls for, breeders should not deliberately breed for it. Masking also gives the face a hard look which distracts from the correct Basenji expression. There is no obvious pattern to its inheritance seen at this time, and it only appears in the few lines that carry it. This masking tendency was never reported in any history of the early African Basenjis and was not seen in the dogs observed in Africa in the 1987/1988 expeditions. This can only cause one to wonder about its origin in the Basenji gene pool in this country.

Color genes that we wish to avoid in our gene pool are the 'Fula' factor, masking, saddling, agouti and diluents.

This chapter has demonstrated how the involvement of many genes act and interact with each other to give us the final coat colors. Even though it is not always this obvious, no gene acts alone.

Chapter 5

SEEING RECESSIVES

When driving up the lane to a friend's home one day, I saw quite an unusual dog standing in the grass in front of the neighbor's white frame house. He was a dark silver gray in color, a shade I've never seen before or since. His coat glistened as the sunbeams bounced off it and the sight was etched in my memory forever. He was of medium size, pendant eared, long tailed, and square bodied, not a pure bred anything but yet familiar looking. My mind whirled because something was strange about this picture. Then my eyes focused on it. The dog's color was not solid but changed ever so subtly to a lighter shade where tan points would have been on a black and tan dog.

I asked my husband (EX) if he noticed the difference in color and got an icy "you must be crazy" stare. Once inside my friends' home, I approached the subject of the dog cautiously.

"Oh, yes, he belongs to the neighbor", she told me. "One of my male Dobes got out when their Weimaraner was in season." Only then did I confess to her what I had seen. She agreed and told me that I was the first person who had noticed it. Perhaps it was because the light was just right, but I could truly see the hidden expression of other than obvious color genes.

Mother Nature gives subtle little hints to the alert breeder about what is present genetically. One of the more obvious, and most commonly known in Basenjis, is the black hairs at the base of the tail in a red Basenji carrying tri. If this black is there, it is a positive indication that recessive black is being carried; however, the recessive may be correct tri or 'Fula' black. If there is no black hair, the Basenji may still be carrying tri and you can only tell from test breeding or a very thorough knowledge of the ancestors. The best time to make this determination is when the puppies are around weaning age. The pure-for-red coats will clear out faster and the tri-factored red will retain the black hair at the base of the tail much longer, some for life; and while some may loose all this black eventually, it is still evident in their youth.

I have noticed that it is usually the reds that have one tri parent that do not show the black on the tail as adults and those with two red parents who do show

it. Logically, one would expect the reverse. It's as though Mother Nature is toying with us, giving help where it is needed but saying, "If you can't figure out the obvious, you'll get no help from me."

"Yes, Jim, you have a question?"

"Can blacks and 'Fula' blacks come in the same litter? If so, can you tell them apart at an early age?"

"Good question, Jim."

Blacks and 'Fula' blacks can come in the same litter. Since there are no tan hairs in the 'Fula' blacks at an early age, it is hard to tell them apart but a discerning eye can see the difference. Look at the skin, especially inside the ears. The true dominant blacks will have 'blue' skin and the skin of the 'Fula' recessive blacks will appear more 'pink' like the inside of a tri's ear.

Have you ever looked at a poor black and white reproduction of a photograph of a Basenji unknown to you and wondered if it was a red or tri? Sometimes it's hard to tell if the cheek is tan with a shadow on it or if the dog is red or even black. Something else can be seen in photos that often escapes the eye. The 'shadow' or 'ghost image' of the P^{tp} tan markings desired on tri-colors can be seen on reds and brindles. On basenjis with little white, you can see that the coat on the extremities of the legs is lighter than the coat on the back. This lighter shade is most noticeable under the tail, vent and breeching and, in the right light, the cheeks of the reds.

I had a litter of two red puppies out of a known pure-for-red dam and by a suspected pure-for-red male. One was the typical looking mousy color of a new born red Basenji with the black guard hairs throughout the coat. The other was different from what I was accustomed to seeing, I called him my 'Golden Boy'. He had no black baby hairs from the start. His guard hairs were brownish and matched the body color. Both puppies showed two shades of coat color with the lighter shade where tan markings should be on a tri. It was particularly obvious on the male with two shades of gold. The guard hairs fell out in about a week and by two weeks you couldn't see any difference in coat color between the two pups. Also, the two shades of red on each of them was no longer obvious. Both were pure-for-red. In a newborn, still wet, tri-factored red puppy, the areas where tan would be on a tri are very obvious, but you should also see the pattern on pure-for-reds if they are carrying both genes for tan markings.

In very bright sunlight, you can sometimes 'see' what a dominant black carries at the "A" locus. If red is carried, you can see a reddish cast to the coat, more so than if tri is present. If you wish to test this, take a black known to carry red, for best contrast one that carries two genes for red, and compare the intensity of black to the coat of a tri color. Or you could use a black that carries two genes for tri, but this would be harder to find. Blacks carrying one gene for red and one gene for tri provide less contrast but will still not be as black as a tri coat. These differences are very subtle and the light must be just right to see them.

Dominant colors are not always what they appear to be because of the interaction of genes. Brindles can be tricky. To understand why, we must first understand brindle. Genetically, it is any dog that carries the "E" series gene e^{br}. In the case of our model Basenji, we hope it has a red base color, preferably caused by two genes for red at the "A" locus. The stripes, hopefully, are black because of the presence of BB and e^{br}. Phenotypically (how it looks), it can be many things. It has a base color with darker stripes. Due to modifying genes, the actions of which have not yet been determined, the stripes may be of many varieties. The stripes may be continuous, or broken. Stripes can be narrow or wide. The stripes may be the same width as the base color, they may be wider than the base color, or the base color may be wider than the stripes. Some stripes are so sparse that the dog appears to be red except on close inspection. Some stripes are so dense or so wide that only a small amount of the base color shows through. These dogs, from a distance, can create the illusion of mahogany if the base color is a good red and especially if both alleles of the "A" series are red, as this can give a red cast to the black stripes. The aforementioned should not be confused with a brindle whose stripes are liver because of the bb genes in the "B" series causing an undesirable rusting of the black. Some stripes can be so far apart as to miss the dog. I have heard these varieties of brindles mistakenly called by many different names. Like it or not, they are all brindles. A brindle is a brindle is a brindle!

Probably we need some terminology to describe the particular patterning of brindle, such as: continuous stripes, disconnected stripes, sparsely striped, heavily striped, narrow stripes, wide stripes, etc.

Now, understanding the above, we can look at what problems it may cause in identifying the correct (genetic) color. I heard of a boxer that had been shown quite a bit in the 'Open Faun' class at shows until someone discovered a stripe on the off (away from the judge) side. This boxer was a brindle.

A Basenji could appear to be a tri-color when in reality (genetically) it could be a 'tri-brindle' whose stripes did not happen to fall on any tan areas. A black could be a brindle whose base color was masked by the dominant black gene. Is this a black, a brindle or a black-brindle?

With a basic understanding of the working of genetics and by observing what goes on around us in nature, we can learn to manipulate genes to suit our desires. By breeding correct colored Basenjis that are carrying correct colors and by segregating these colors, we can breed colors predictably. By breeding dogs that will not create any unwanted colors, we can prevent any confusion in future generations. One way to help novice breeders in the future would be to have a color code of ethics for this breed just like the Great Dane national club has.

As stated before, the world is a classroom - use it. Look closely at all the wonders of nature with an open mind. Look all around you, observe your own breed and other breeds. Ask questions of the owners of dogs with colors you find interesting. Nature has a very organized scheme. We only need to understand it.

Chapter 6

A REVIEW OF THE ACCEPTED COLORS

There are some questions that need answering. Since the "A" series has been credited as having its own dominant black, A or A^s, some of you are wondering if that is not what causes the dominant black in Basenjis. This may be what you have seen in print elsewhere.

Look back at Chapter 2 where we talked about the inheritance of traits. Remember that one chromosome came from each parent, and that the chromosomes in the new individual are in pairs. These are gene pairs and each gene pair is in a specific pre-determined order. Their specific place on the chromosome is called a locus. There are **always** <u>**two**</u> genes at each locus. Never more, never less. There may be two, three, or a hundred alleles in a series that may appear at any one locus, but only two of them may be present at one time in any animal. They may be two different genes or two like genes.

Remember, we are now discussing having only the accepted colors. When the first three-colored litter was produced from one black parent, no one understood how it happened. There are several combinations that will give you these results. For the sake of argument, let's say that the dominant black in Basenjis is the A or A^s of the "A" series.

Now, watch what happens in the real world using this theory.

Example #1

We have one black parent, for dominant black can come only from dominant black. Therefore, we have A as one of our alleles. Let's say the other allele is tri, a^t. So we have two allele at locus "A", this parent is Aa^t.

The other parent is red, but tri-factored. The genetic makeup at the "A" locus is a^ya^t.

So, if the A from the first parent is present, the puppy will be black regardless of which gene the other parent contributes because the black, allegedly, is dominant to both red and tri. Now we have our first color.

If the first parent contributes the other gene, a^t, and the second parent contributes the a^y gene, the puppy will be red because red is dominant to tri.

Now we have our second color.

If the first parent contributes the a^t gene and the second parent contributes the a^t, we have tri. That's the third color.

"So what's the problem?" you are asking. There is no problem if you understand it so far, but this is only one scenario.

Example #2

I imported a black male from England when blacks were first appearing in this country. He was bred to a clear tri bitch. The puppies in the resulting litter were all either black or clear tri. What can we deduce from this? We know the tri is a^ta^t. We knew the black was A, and now we know he is also a^t. Right? Simple deduction! No problem so far.

Example #3

The same male as example #2, Aa^t, was bred to a tri daughter of the bitch in example #2 (not sired by the black male). This bitch is a^ta^t. What are the expected results?

You say tris and blacks. Right? That's all there can be.

When my phone rang on the due date of this litter, I knew who was calling and that the bitch had whelped. Imagine my surprise when the voice on the other end said, "Why do I have a red puppy?"

"I give up, where did you get it?"

"It's in my litter with two blacks and a tri."

Now my wheels were spinning! The bitch had been with me until she was well out of season, so I could hardly ask my friend if she had gotten loose on her. She knew me well. "She wasn't around any other dogs here", she assured me.

"She wasn't with any other dogs here either," I replied. "Are you sure it's red?"

"Yes, it's red!", my friend replied. I had to believe her, she was not a novice about breeding or dogs, although this was her first Basenji litter. "I don't know," I confessed, "I've heard of other three colored litters, but I don't see how this one could have a red. Let me think about it and I'll call you tomorrow."

At the time, I too thought the black was an allele of the "A" series. That night I went to bed early with my 'bible', "GENETICS OF THE DOG' by Burns and Fraser. They had all the answers. The light burned late.

The dam of the litter was a tri. She could not have any genes for red. The sire was black. He carried the tri gene as evidenced by his previous litter and the tri in this litter. So, where did the red gene come from? It had to be from the sire. But if the sire carried red, where did his tri gene come from if the other allele was black. There can't be three alleles at one locus.

My thoughts returned to Paramoure's questioning of whether or not tri and red belonged in the same series. I tried to work things out using that theory, but knowledge of past litters of Basenjis, Collies and Shelties would not fit that scenario. I could only conclude that it was the black that had to be in a different series. Using this theory to work through many litters that I knew about proved

it to be correct. Therefore, I concluded that the black of Basenjis was not A or A^s. It was not until many years later that I realized what other series worked for the black.

This is the basis of my theory. The dominant black in the Basenji breed is the result of BB and at least one E, with the alleles of E being e^{br} and e. The e^{br} is recessive to E and dominant to e. The "E" series genes present in reds and tris are ee. While the ee is hypostatic to the red, I feel it may serve to enhance the depth of color. The ee is also hypostatic to the recessive black of the tri and is probably the pigment gene responsible for the tan points when the patterning gene(s) limit(s) the black to the bi-pattern.

For our colors to work in our Basenjis, the only two genes that should be at the "A" locus are red and tri. They may be in any of the following combinations: a^ya^y, a^ya^t, or a^ta^t. How do I know this??? Logical deduction. It has proven itself to be true in breeding.

Our black can have, genetically, any of the following makeups:

BB, $P^{tp}P^{tp}$, Ee, a^ya^y

BB, $P^{tp}P^{tp}$, Ee, a^ya^t

BB, $P^{tp}P^{tp}$, Ee, a^ta^t

BB, $P^{tp}P^{tp}$, EE, a^ya^y

BB, $P^{tp}P^{tp}$, EE, a^ya^t

BB, $P^{tp}P^{tp}$, EE, a^ta^t

BB, $P^{tp}P^{tp}$, Ee^{br}, a^ya^y

BB, $P^{tp}P^{tp}$, Ee^{br}, a^ya^t

BB, $P^{tp}P^{tp}$, Ee^{br}, a^ta^t

Let's apply the same relationship of the "A" and "E" series to brindles. Say we have our ideal brindle with black stripes on a red background. He is BB, which can create a black coat. He is e^{br}, which permits the partial extension of black (stripes), and e, which enhances, or at least compliments, the red body color and allows for tan points since he is also $P^{tp}P^{tp}$. His "A" series alleles are a^ya^y, thus the red background of the coat.

All brindles of this phenotype are not always 'the ideal'. Since we are working with all the genes we need for all of the correct colors, there can be other variation in the genetic makeup of a brindle such as:

At the "E" locus, we could have $e^{br}e^{br}$, making our individual homozygous for stripes. At the "A" locus, we could have an a^ya^t, with one discernible difference to the phenotype being a barely perceptible deepening of the black stripes. The only way we could tell for sure would be in future breedings. However, an experienced eye may be able to discern the black in the tail designat-

ing tri-factor in the more lightly brindled pups. The other possible combination would be $a^t a^t$, resulting in a tri-color with black stripes showing on the tan areas if the stripes were extensive enough.

A brindle's genetic makeup can be any of the following:

BB, $P^{tp}P^{tp}$, $e^{br}e$, $a^y a^y$

BB, $P^{tp}P^{tp}$, $e^{br}e$, $a^y a^t$

BB, $P^{tp}P^{tp}$, $e^{br}e$, $a^t a^t$

BB, $P^{tp}P^{tp}$, $e^{br}e^{br}$, $a^y a^y$

BB, $P^{tp}P^{tp}$, $e^{br}e^{br}$, $a^y a^t$

BB, $P^{tp}P^{tp}$, $e^{br}e^{br}$, $a^t a^t$

Genetically, our reds look like this so far:

BB, $P^{tp}P^{tp}$, ee, $a^y a^y$

BB, $P^{tp}P^{tp}$, ee, $a^y a^t$

Our tris are:

BB, $P^{tp}P^{tp}$, ee, $a^t a^t$

This is not the entire genetic color makeup but just the gene pairs pertaining to this study where the alleles may vary to create different colors and/or patterns. The following are some gene pairs for other series' alleles that should be ever present in homozygous form:

DD mm CC tt S^iS^i

For your homework, copy each of the genetic makeups onto a piece of paper. After each, write the color of the phenotype and what colors each makeup can produce.

Example:

BB, $P^{tp}P^{tp}$, Ee, $a^y a^y$

This Basenji would be black. It would carry the factor for tan points, the pigment for tan, and red. (Pure-for-red). Properly bred, it would produce only black and red puppies.

See if you can interpret all the symbols in this way.

Chapter 7

WHITE MARKINGS

In order to understand the inheritance of white markings, we must look at yet another genetic series. This is the "S" locus, a very interesting locus that affects the distribution of white and colored areas throughout the body. While the "S" series gene determines the basic pattern of white and colored areas, there are also modifying factors that cause the amount of white to fluctuate around a given mean of distribution at each locus. This causes overlapping of the expression of the genes in this series.

The "S" locus alleles in order of dominance are:

S - self, or completely pigmented body surface (no white)

s^i - Irish spotting (sometimes called Dutch markings)

s^p - piebald spotting

s^w - extreme white piebald

The S needs little explanation as it refers to solid colored dogs, such as the Schipperke or Labrador Retriever.

The s^i is the allele that we are dealing with in the Basenji dog and its range is well covered by the Basenji standard. Another example is the Shetland Sheep-dog.

The s^p can cover a lot of area and overlap the areas of s^i and s^w because there are a lot of 'plus' and 'minus' modifiers that affect the extent of the color areas in this series. But, basically this is an animal that is 50% or more white with colored spots or patches. Examples are: the Fox Terrier, Brittany Spaniel, and Clumber Spaniel.

The s^w creates an all-white body such as the Samoyed, Great Pyrenes, Sealyham Terrier and White Bull Terrier. In the Bull Terrier standard, a colored spot on the head is acceptable, but on the body coat it is a disqualification. As mentioned before, the body markings are inherited separately from the head markings.

In Bull Terriers which have both white and colored varieties, the white to white breedings produce only white puppies. Some have all white heads and some have color spots on the head. These color spots are very helpful if one

wishes to breed colored Bull Terriers as they may indicate what color is carried by the white animals. Some colors are preferred over others with brindle being the most preferred color. Color-bred-whites bred to colored will produce colored offspring.

This was to give you an idea of the range of white markings, but from here on we will deal with the ones that concern the Basenji, the s^i.

The Basenji standard says of the four colors, "all with white feet, chest and tail tip." This is the minimum allowed which keeps the breed at the s^i for white and prevents it from becoming S with no white. The maximum allowed by the s^i series permits a blazed face, white legs and full collar. The standard goes on to say, "The amount of white should never predominate over primary color." If it should, the breed could be in danger of slipping into the s^p or piebald category. Therefore, it is important to keep the alleles for white homozygous for the Irish spotting factor, s^is^i.

Now it is time to return to our model statues of the Basenji. So far, we have only made solid colors - red - tri - black - brindle. It's time to add the trim. Take your brush and give your Basenji his white. The white markings go on top of everything else and conceal what is underneath. Let's look at what this may mean to us if we are trying to determine the color genetics of a certain dog.

I see that Harry has given his tri high white stockings all around and very little tan can be seen. Are you sure this is a tri or is it a tri-brindle with no stripes visible? Is it a clear tri or is the tan bleeding into the black under the white back legs where you can't see it? We'll have to watch the head very closely. I'd like to see a little more tan for a clear tri, and look here, there's a slight dip in the black down into the tan of the cheek. Is this indicative of a 'Fula' bar, a part of a brindle stripe or no problem at all?

"No problem at all!", Harry tells us, "Both parents were clear tri and there is no brindle or 'Fula factor' in the pedigree."

O.K., we're safe on that one, but I see Mary has dripped paint onto the back of the red statue that Doris has. The white spot is small but in the middle of the back. It is not a place that was once connected to the collar that was closed off by the color. This is a mismarked Basenji, possibly carrying a piebald, s^p, gene. Breeding from this dog would be a risk.

"Not to worry," says Doris, "he's neutered!"

My, this class is sharp today, but what about these white streaks behind the elbow extending up into the body color on Jon's statue?

"The collar cuts way back into the body color on the other side", notes Anne, "and there is white extending up the flank also. This dog is either carrying a gene for s^p or the modifiers have been hard at work. A poor risk for breeding."

I see Jenny has a black Basenji statue that has very irregular markings, is there some reason why you chose to paint it that way?

"Yes," said Jenny, "most of the black and whites I have seen did not have symmetrical markings."

That's very observant. Perhaps the genes for black and the ones causing asymmetrical markings are located on the same chromosome.

"Are these markings incorrect?" asks Bob.

Not as long as the white is in an acceptable area and not where black should be. Some people feel that asymmetrical markings cause optical illusions for the judges, causing them not to be able to assess conformation and movement correctly. A good judge should be able to see past markings.

An island of white in an area that should be colored is a serious fault. An island of color in a white area is permissible if that is an area where the color should be if there was a minimum of white markings. There is nothing wrong with a color spot in a collar or in a white stocking.

Occasionally you may see a Basenji with a very small amount of white on its feet. Sometimes only one or two toes are white. When this happens, we must guard against slipping too far toward the extreme of no white or the S allele.

Although excessive face markings usually go with a lot of white on the body, they are inherited separately. The wider the blaze, the more it takes away from the expression of a Basenji. Here again, modifiers may play a role. If wide blazes are encouraged, they can get out of hand and end up as an all-white head or a white head with a colored spot or two. When the blaze is so wide that it touches the eyes and reaches or obliterates the pips on tris, it is excessive and should be discouraged in breeding.

I knew of a litter where the sire had a narrow blaze and the dam a moderate blaze and two of the pups had white heads with the only color being on their ears. All the ancestors in the pedigree for seven or more generations were Basenjis known personally by me. The only ones that had a large amount of white on their heads were a mother and daughter who did appear once on each side of the pedigree. The mother had a very wide blaze and the daughter's was not only wide but fell off one side of the head further than the other. I do not now how their littermates were marked. The daughter was in the sixth generation behind the sire and in the fourth generation behind the dam of the white headed puppies. Both sire and dam produced many other litters without any mismarks when bred to other mates. There were never any excessive body markings produced.

The Collie is a good example of a breed in which breeders have managed to breed plain heads while retaining full collars and other white markings on their dogs. White is an acceptable color in Collies. There are white bodied dogs with some color spots and a colored head. Unfortunately, in the Shetland Sheepdog, white is not an accepted color due to politics early in the development of the breed in this country. These breeds are good studies of "white factoring".

A "white factored" dog is one that exhibits white stockings that run up the hind leg above the hock. Usually this is seen as a strip of white up the front of the rear leg reaching to or past the stifle. In Collies and Shelties, when both parents exhibit the white factor, they are capable of producing white offspring.

The usual genetic white for these breeds is $s^i s^i$. The "white factored" dog would be $s^i s^p$ or $s^i s^w$. Plus and minus modifiers can confuse the exact difference between each of these series.

There is also another way for white to be created that has nothing to do with the "S" series, but I'll mention it here since we are discussing Collies and Shelties and they are among the breeds that deal with merle, the "M" series. M is to merle and m not to merle. The merle effect is caused by a dilution of pigment of part of the color but not all of it.

The most popular is blue merle, that is a 'blue' with irregular black patches. In the above breeds, it is the effect of the **heterozygous** merle genes (Mm) on the black of a tri color coat. Breeds that do not have merle, like the Basenji, are mm at this locus. The **homozygous** state of merle (MM) causes the individual to be white or nearly white. The phenotype of this animal will look the same as a white Collie with blue merle spots but is genetically different. The MM animal will be wholly or partially deaf and blind. This is an example of the expression of genes linked to color.

Breeders usually breed blue merle only to tri for this reason. If merle to merle breedings are done, the 'whites' are usually destroyed. However if a 'white' merle (MM) is bred to a tri, the breeding will produce all normal blue merles without any defects of sight or hearing.

Probably the most unusual and least understood of 'white' dogs is the Dalmatian. Here there are several series involved. A good quality of clear white is needed for the background color which is probably provided by s^w as the whole dog can be pure white but patches do occur. These patches of color are present at birth which is how they can be distinguished beyond any doubt from the correct round spots of color which do not appear until the puppy is about two week of age. The accepted colors for Dalmatian spots are black and liver, obviously the "B" series. Black and tan spots (the genes creating our tris which are from the "A" series) are a disqualification in Dals.

Little feels that the "T" locus for ticking is responsible for the color spots in Dalmatians because the 'ticking' in other breeds is not present at birth but appears later also. There must be other, yet unknown, influences that give the spots their size and round shape. Dals also tend to be deaf, again related to the white gene. While ticking is sometimes seen in Basenjis, it is very rare and easily replaced by clear white. The majority of the ticking I have seen in Basenjis is from lines that contain dominant (Liberian) blacks. It is presently being seen occasionally in lines of brindle breeding.

Chapter 8

MARKERS, LINKAGE AND CROSSING-OVER

Lately, we are hearing a lot about 'marker genes'. What is a genetic marker? In Chapter 2, we briefly touched on linkage. Remember our basic unit of inheritance, the chromosome? We noted that all the genes on the chromosome were linked together. A 'marker' is a specific gene that can be identified on the same chromosome with another gene or genes for a trait that researchers wish to trace. When the trait they wish to trace is not easily identified, they trace the marker gene to determine the inheritance. They are assuming that when the marker gene is present, so is the trait they wish to follow because they are **linked** on the same chromosome.

Are markers a recent discovery?

Not really. Successful animal breeders have been using them for many years. Markers are not just genes seen under the microscope but little clues that nature gives us in real life. One of the most obvious markers best known by Basenji breeders was discussed earlier. It is the black hairs on the top side of the root of the tail on a red dog which tells us that the Basenji showing this carries tri recessively.

Here is another example. When I first started the line of Basenjis that I am continuing now, my foundation bitch was a clear tri-color. One of her faults was a weak top line. I bred her to a pure-for-red male with a very strong, level top line to correct it. I was lucky in that this next generation all showed improvement in their top lines.

I kept a red bitch from this breeding who was, of course, tri-factored, but had the hard level topline I wanted. When looking for a mate for her, I would have preferred a tri or tri-factored red so that I could get back to having tri-colors. As I also knew I needed to further fix the strong top line, that was another thing I was seeking in the stud. I was looking in the same family as I wished to line breed. The only acceptable dogs with strong toplines were pure-for-red, so I picked the best one.

After several litters from this bitch, each by a pure-for-red, I was wondering if I would ever have a tri again. It was getting so that I could look at a dog's top

line and tell you if he was tri-factored or not. All the tri-factored dogs had a softer top line than the reds and all the tris were even worse. The genetic marker for soft toplines - the tri genes. We'll come back to this bitch later.

In the '60s, I had a friend who had Dobermans; I had a few myself. We were interested in finding a good red and so we watched the Dobes in the ring at every show. Soon a pattern began to appear. Every red had the same fault, a rounded croup and a low tail set. This was in contrast to the blacks that mostly had more level croups and higher tail sets. Color again was a genetic marker. This is not to say that all obvious markers are color, but these are good examples as color is basically what we are looking at in this study. In years since, Dobe breeders have corrected this problem and now you can find red Dobes with croups and tail sets as good as the blacks.

One more example of a color marker linked to conformation is the white above the hocks in Basenjis. Nearly every time you see the white running considerably high above the hock, you will notice that the dog has the same kind of rear. It is lacking in angulation at hock and stifle, plus the dog is high on the hock with proportionately shorter thigh and second thigh. The markings accentuate this effect, but if you can look past the color you will see that it is more than just an illusion.

Linkage can be seen when traits are inherited on the same chromosome. This should answer a hypothetical question from earlier. If all the genes controlling voice and all the genes controlling hair color were linked on the same chromosome, except, of course, for the gender difference, **yes**, Sally, all redheads **would** sing soprano!

Yes, you have a question?

"Red Dobermans have just as high tail sets as the blacks now. If the low tail set was on the same chromosome as the red color, how could it change?"

A good point, Robin. It's for the same reason my present tris don't have soft toplines. It's time to discussing crossing-over.

Meiosis is the mechanism by which genetic material is passed from one generation to the next. The cells of sexual reproduction divide differently from those of growth. To grow the cells duplicate themselves by a mechanism called mitosis. In meiosis, the chromosome pairs split up with one strand of each going to opposite sides of the cell. When these cells divide to form sperm or ova, one of each pair goes off in a separate gamete. When the final division is complete, there are 39 single strand chromosomes in each new cell. Therefore, when the 39 chromosomes of the sperm join with the matching, but different, 39 chromosomes of the ovum, a new life is formed with 78 chromosomes, or 39 pairs of chromosomes.

Now we can go on to crossing-over. Normally, genes linked together tend to stay together. Here is the exception. Although an animal must transmit the full quota of chromosomes, it **can** transmit parts of one chromosome linked to the other parts of its partner chromosome. At a certain stage during meiosis, a

chromosome may become transposed with a similar piece from its partner. At the subsequent division into gametes, these two pieces will now go off with the other part of the partner chromosome. Therefore, the linkage between certain genes is broken and some of the genes that once traveled with the chromosome inherited from one parent are now linked with the genes from the chromosome of the other parent.

The further apart genes are on the chromosome, the more opportunities there are for cross-overs to take place between them. The closer they are located to each other, the less opportunity there is for a cross-over to come between them.

Now, let's get back to my Basenji bitch from whom I wanted to get a tri. Age dictated that this would be her last litter, so if I was to have a tri from her, it had to be now. I was in luck. A litter sired by this bitch's grandson contained the dog for which I had been searching. He was a tri-factored red with a solid top line and a good specimen of the breed. In him, the linkage had been broken. From this breeding, I got the tri I wanted with the good top line which is breeding on to this day.

As pointed out, present red Dobermans have croups and tail sets as good as the blacks'. This can be attributed to diligent selection by breeders when cross-overs occurred that broke the chain connecting the low tail set with the red color.

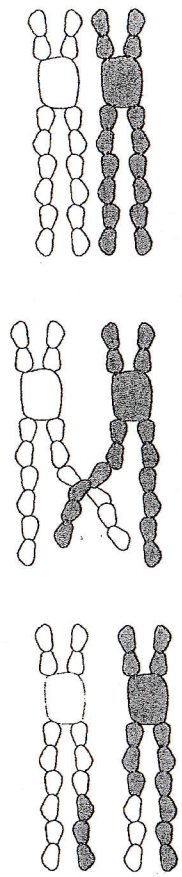

Figure 5 - This illustrates how a cross-over occurs. There is a breakage and reattachment of part of the chromosomes which create a recombination of the genes.

Cross-overs occur fairly frequently. Probably most go unnoticed. The alert breeder with experience can train himself to be on the lookout for traits that are linked as a way to preserve things that he wants to keep and for cross-overs to discard traits he wishes to separate from those he wants to keep.

Perhaps you have heard that two siblings can be totally unrelated to each other. Is that possible?

In meiosis, when the cells divide, one of the chromosome pairs goes one way and the other the other way. These two gametes are different. The same thing occurs with the other parent creating two more gametes that are different from each other. A gamete from one parent recombines with the gamete from the

other parent to form a new zygote. The results can be very different. Totally unrelated in theory may work, but in the real world, some of the genes that go their separate ways are the same kind of genes (homozygous), so there will always be similarities in siblings as well as differences. If the parents are a result of out-crosses, many of the genes will be heterozygous and there will be more variation in the siblings. If the parents are line-bred, then more of the genes will be homozygous and the siblings will be more consistent in type.

"Is this crossing over something like a mutation?", asked Shirley.

Not exactly. When a cross-over occurs, the genes merely change their location to another chromosome, but the genes remain the same. A mutation occurs when the gene itself changes. Such things as radiation, chemical reactions or even smoking marijuana can cause a gene to mutate. If the mutant gene is in the sex cell, the mutation will be passed on to succeeding generations.

For example, a few years ago, a mutation took place in a bitch and she produced hemophilia in her puppies.

"Isn't that the bleeding disorder that affected a royal family in England?" Joan asked.

Yes, and being a disorder in humans quite a bit is known about it. The blood does not clot so those who have it are always at risk of bleeding to death. The inheritance is sex linked. It is transmitted by the female, who is not affected. Only the males produced by a carrier female are affected.

"Bob, you look puzzled."

"Well, how do you know it was a mutation and not just inherited?" questioned Bob.

The bitch was from an extensive and well-known family. The relatives for many generations were known, shown and bred from by many people and there were never any signs of hemophilia before. The same applies to the sire, although genetics from him would not have been involved anyway. An expert on blood disorders was consulted and it was ruled the result of a spontaneous mutation.

Chapter 9

THE BIG PICTURE

"Gene pool" is an ambiguous term at best. Just what does it mean? If one is referring to the gene pool in its broadest sense as related to canines, it would have to mean every possible gene that can be present in all canines. We're talking many billions of genes. These genes create all domestic dogs, wild dogs, wolves, coyotes and anything else with 78 chromosomes. This is the gene pool for all canines.

When you realize how many genes are involved, it is not surprising that there can be so many different breeds of dogs in the world today. It is a wonder that any two look at all alike with this kind of diversification. So, just how did the different breeds come about?

Selection is the key word. Whether by nature or man, it is the selection of certain traits that creates a specific type of individual. "Form follows function." If an animal had to function in a certain way in a particular environment, the physical conformation and mental ability would develop in that direction, for only those that did would survive to reproduce. This would develop a sub-species of canine by intensifying the use of certain genes and losing other genes' alleles that had no significant value. Now another gene pool is formed for this sub-species as there is less variety of alleles at many of the loci on the chromosomes.

For example, the Shetland Islands are a group of small islands in the North Sea off the coast of Scotland. Hammered by wind, wave and rain, they suffer long winters and short summers. There is little fertile soil for crops and life verges on starvation much of the time. Diminutive ponies, cattle and sheep, as well as dogs to herd them, have evolved there, shaped by the harshness of life. By natural selection, the sheep dogs of this land developed into small, strong hardy workers.

The further selection by man narrowed the gene pool even more. There was no need for a larger dog as the sheep were small and the food was scarce. The sheep were agile and quick with great jumping ability, so fences were of little use. Therefore, the sheep dog needed to have the instincts, speed and stamina to

drive the sheep out of the gardens and homes and back to the hills. These dogs were first selected by humans for their working ability.

There are varied theories as to the origin of the ancestors of these dogs, and the early history of the Shetland Sheepdog is very vague. Later, the islanders often brought in small Scotch Collies which interbred with the native stock, but selection was still based on working abilities.

When fashion demanded that these dogs be bred smaller for pets, alien blood was introduced which brought discredit to the native working dogs. Islanders found it was more lucrative to breed to size rather than type as there was a demand for small, fluffy pets whose purchasers believed they were getting genuine specimens.

Since the original Shetlands had neither the consistency of type nor the pure breeding to become a show breed, crosses to the show Collie were utilized. Although the crosses probably brought in new genes, the gene pool was eventually narrowed again as humans began selecting for phenotype. Many generations of breeding to the standard have given us the Shetland Sheepdog of today, selectively bred to size, certain colors, type and movement.

This was done by eliminating unwanted genes, such as those for domed heads, and intensifying the desired genes for the traits that set the Shetland Sheepdog apart from all other breeds of canines. This gave the breed its own breed gene pool.

Now you can see that there is a total canine gene pool (more like an ocean) a sub-species gene pool (decided by geographic isolation), and a breed gene pool (decided by the breed clubs). To refine it further, there is the line/family gene pool of related dogs within a breed. This is created by a breeder or breeders who desire certain variations within the framework of the standard. And finally there is a gene pool of a particular individual which includes only the genes carried by that dog within himself at that time. When talking about the gene pool, it helps to clarify the term.

In order to breed a dog that is precisely what you want and expect it to reproduce in kind, you would have a slim chance if his genes were chosen randomly from the total canine gene pool. You would have a better, but slim, chance if the genes were chosen randomly from the sub-species gene pool. But if the genes were chosen randomly from a breed gene pool, you could expect to get something that was at least recognizable as that breed. You would still have millions of genes to play with.

What if that wasn't good enough for you? What if you wanted something close to perfection to show, to course, to hunt or to work stock? Where would you go?

Look for a line of dogs within your breed that has the qualities that you desire. This is the starting place. Look at pedigrees and related dogs to determine if the attributes you want to perpetuate are present in the family gene pool. If they are not there to start with, there is no way you can get them from this line.

Balance the things you like against all the things in the line you don't like. You will get both no matter what. If the positives outweigh the negatives, you can then begin to create what you want. Select for the desired points while eliminating the faults and weaknesses. Learn the laws of genetics and apply them to your knowledge of dogs. Learn all you can about as many dogs in your pedigree as you can, not just names, wins and titles, but genetic facts. Don't limit yourself to the names on the pedigree, but look at all the siblings of all those dogs and get a broad view of the genes in that gene pool. Plan your breeding program genetically. Acquire enough knowledge to be able to read your pedigree between the lines. This is the key to successful breeding.

Don't expect to change the world in one generation. Breeding is slow and arduous work which does not give you instant gratification. If you have the desire to create, the patience to learn, and the intestinal fortitude to persevere, you can develop a line of dogs that you can look at with pride. You can be content with the knowledge that they will carry your improvements into the future.

Your dogs will each have 78 chromosomes with the whole compliment of genes, but by careful **selection,** over time you can determine which of the eight billion genes you wish to have in ***your*** line's gene pool and which you do not wish to have.

Chapter 10

APPLYING OUR KNOWLEDGE

Hopefully, the previous chapters have shown you that genetics, while complicated, can be understood. No gene acts alone; all are influenced by other genes acting in harmony to create a certain effect. They are turned off and/or on, intensified or diminished, in a symphony conducted by nature reading the blueprint of DNA. For the most part, the music will continue with or without our help or hindrance. But if we take the baton away from nature, we should know how to lead the orchestra. When we override natural selection, our selection must be wise and based on the same logic as natural selection. Temperament, health, and soundness must lead the parade, followed by the ability to function in the capacity of the design — type.

If we are going to play God, we must put aside our human frailties and not select for personal reasons. We must select first for what is best for the breed as a whole. Too many breedings are made for the wrong reasons such as:

Breeding to the big winner
The big name (heavily advertised dog, handler and/or owner)
The politically correct
The type that is winning at the time (fad)
The most convenient
To have more marketable puppies

These things have nothing to do with genetics or improving the breed. Once the groundwork has been laid for the characteristics of temperament, health, soundness and the important things that will assure the future of the breed, there is still room for the 'personal' touch. But ignore the basics, and ruin the breed.

QUIZ TIME! Let's see what we've learned.

Test

Section A

For the following ten questions, we will assume that we are working with all the correct Basenji colors to meet the standard and that there are no unwanted color genes present in these breeding animals. The allele of black and brindle is e (tan) for all of Test #1. You are given the color and any recessive colors of the "A" series of the breeding pairs. List **all** the possible color combinations you could expect to get in the resulting litters.

Example:

Question: Pure-for-red X tri-factored red?
Answer: Pure-for-red and tri-factored red puppies

1. Tri-factored red X tri-factored red?
2. Black (two genes for tri) X pure-for red?
3. Brindle (two genes for red) X brindle ("A" series unknown)?
4. Black (red & tri) X pure-for-red?
5. Black (red & tri) X tri-factored red?
6. Brindle (two genes for red) X pure-for-red?
7. Brindle (two genes for red) X tri-factored red?
8. Pure-for-red X pure-for-red?
9. Black (red & tri) X black (red & tri)?
10. Black (two genes for red) X pure-for-red?

There, now, wasn't that fun?!

Section B

You will be given information on the two Basenjis to be mated, only this time you may have to deduce what the recessives may be. This time, they may not always be accepted colors. List **all** the possible color combinations you could expect to get in the resulting litters.

1. Red (?) X tri-factored red?
2. Black (sire is black out of a 'Fula' tri and dam is red showing no sign of tri-factoring) X pure-for-red?
3. Brindle (two genes for red) X tri?
4. Black (red & 'Fula' black) X brindle (red & tri)?
5. Brindle (sire is brindle - "A" series unknown) X red (sired by a tri)?
6. Tri X tri?
7. Tri X 'Fula' tri?
8. Brindle (pure-for-red) X tri-factored red?
9. 'Fula' tri X 'Fula' tri?
10. 'Fula' factored red X 'Fula' tri?

Hopefully, if you've been paying attention to the previous chapters, you were able to ace this test. If not, review the chapters pertaining to the parts you still don't understand. Answers are in the back of the book so that you can see how much you've learned.

The knowledge and skill that you have used to work through these problems of color can be applied to any other trait you wish to change. If you understand how all the answers were arrived at, you are thinking genetically. Genetics is like mathematics, once you understand the basic formulas and how they work, you can apply them to any problem. It's all a matter of logic.

FIXING OR ELIMINATING TRAITS

The traits that you select to create your perfect dog are ones that you wish to retain in the future. How do you go about doing that? Which are the easiest to keep, the dominant or the recessive characteristics? Be careful now, this one may fool you.

The dominant genes are always expressed in the phenotype so that you can see them. Take our dominant black, for example. If it is in the gene pool of a Basenji, that Basenji is black. If he is not black, then the dominant black is not in his genes. In order for him to product dominant black in his offspring, he must be black, just as one (or both) of his parents must have been black. The same applies to brindle (striped). Once a dominant trait is gone, it's gone. The only way to get it back is to breed to another individual that possesses that dominant gene or genes.

On the other hand, if it is a dominant characteristic you wish to breed away from, it is very easy. You select animals that don't exhibit that characteristic.

Recessive characteristics, however, are a horse of another color. (No pun intended.) In order to retain these characteristics, the gene(s) must come from both parents. If the characteristic is displayed, it is easy as this animal is homozygous for that characteristic and will breed true for it as that gene is the same at each half of the locus. This will be passed on to all offspring. However, if the same gene is not inherited from the other parent, it will not be evident.

An animal that has inherited two different genes at a locus is said to be heterozygous for that trait as it will produce two different germ cells with respect to that gene. The characteristic that you desire can be produced by this dog, but only about 50% of the time if the inheritance is dependent upon a single gene. In other words, the dog carries the recessive for this trait even though it is not expressed in his phenotype. Example: the tri gene is carried recessively by a tri-factored red. In order to bring this recessive to the fore, you must breed to a mate that also carries this tri gene; when an offspring receives the tri gene from both parents, it will be a tri-color (provided the "E" series doesn't interfere).

In order to preserve characteristics that are inherited recessively, one must

have a greater understanding of the animals that are being bred because the recessives are not always obvious. If the recessive gene you desire is plentiful in the family you are working with, it becomes easier to bring it to the fore.

On the other hand, if the recessive is a trait you wish to eliminate, this can try one's patience. Theoretically, a recessive gene can lie hidden for a hundred generations without expressing itself if it does not happen to meet up with a like gene.

"Yes, Robin, you have a question?"

"Is it easier to lose a recessive than it is to preserve it?"

"That depends," Tommy spoke up. "If it's a trait you want, it will be easily lost; if it's one you want to get rid of, it will hang on for many generations!"

"Is that one of Mendel's laws?" John asked.

"No," grinned Tommy, "Murphy's!"

A good example of just how long a recessive gene can lie hidden is the case of a Basenji which came down with Hemolytic Anemia in recent years. HA is a deficiency of pyruvate kinase which is inherited in Basenjis as a single gene autosomal recessive. A test for carriers was developed in the 1970's and the problem was nearly stamped out. Occasionally the gene slipped through the screenings or was carried on by breeders who did not test or who were uninformed about HA. When researching the pedigree of this recent HA dog, it was determined that the closest ancestor known to be a carrier was in the fifth generation on the sire's side and it appeared only once. This was one ancestor out of 32 in the fifth generation. This same carrier bitch also appeared on the dam's side, once in the eighth generation and, again, once in the ninth generation. The only other known carrier was a dog in the seventh generation on the dam's side. It is not known how many more generations one would have to go back to find the affected dogs in the pedigree. The HA gene from an ancestor five generations back lay hidden until it met up with a like gene from seven, eight or nine generations back on the dam's side before it expressed itself. Only four ancestors out of 1,024 were known to be HA carriers until it appeared again.

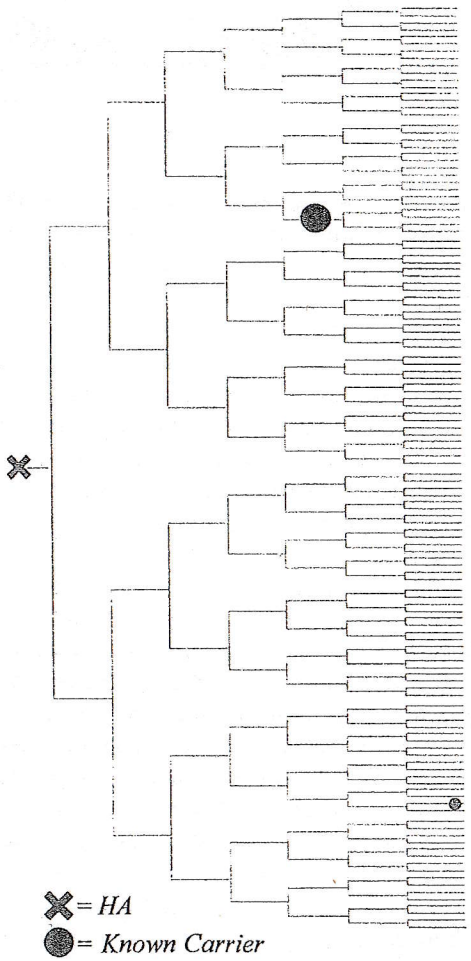

Figure 6 - A recessive gene can lie dormant for many generations as seen by this pedigree. The symbols show where the expression of the gene was last evident as a carrier before expressing itself in this animal.

So, what new knowledge have we gained from knowing that this particular dog has HA? We now know that all individuals in direct descent from the carrier on the sire's side are all carriers also. On the dam's side, the gene has descended from at least one of those carriers. Now every individual in direct descent from all three places must be considered suspicious of carrying the HA gene.

For those who understand the workings of computers, it may be easiest to understand inheritance if you think of it in terms of the binary system. The passage of a gene from one generation to the next is a yes - no, true - false, go - no go situation. At the time of meiosis, if the gene we are tracking is homozygous, it will be passed on to the next generation regardless of which gamete is responsible for creating the new life. This is a definite **go**. If the gene is heterozygous and the gene we are tracking divides into the gamete that forms the new individual in our pedigree then this is also a **go** and passes on to the next generation. However, if the gamete that produces the next generation contains the allele to the gene we are tracking instead of our gene, that is a **no go** and the gene does not pass on in direct descent in the pedigree. Genes can trickle down through many generations in this manner, or they can stop at any time.

PRA (progressive retinal atrophy) is a good example of a characteristic that one would wish to eliminate from a breeding program. Some types of PRA in some breeds are inherited as a single autosomal recessive. This is what we have in the Basenji. How does one go about eliminating this?

"John, tell us what you know about this problem?"

"Well, it's a disease of late onset, so it isn't usually evident until an animal is around five years old or older. If you bred older animals that don't have the problem, you would have a better chance of having normal eyed offspring."

"That's good so far, John. Does anyone else have anything to add? Yes, Ann?"

"Knowing that neither parent has PRA only tells us that they don't have two genes for the disease. Either or both could still carry it."

"Right, Ann. So what would you like to know about the pedigree of these animals that would help you in your breeding decisions? Mary?"

"I would like to know the eye status of the parents of each of the animals considered for breeding and, if possible, the grandparents' eye status also."

"Yes, that would be very helpful."

Let's take a hypothetical situation and discuss the possibilities of developing a genetically clear line of Basenjis. We have a prospective dam who shows no sign of PRA at five years of age. Her sire and dam are testing normal eyed for PRA. Three of the four grandparents were normal eyed at an older age. The status of the fourth grandparent's eyes is unknown. However, we do know that the unknown grandparent has a sibling with PRA. This means that the unknown grandparent could carry one or two genes for PRA. So, PRA was present in at least one place three generations before our proposed litter. We must be aware that the possibility of a PRA gene in this bitch does exist, even if it is a small possibility. Now to look for a sire.

Sire #1

This dog's dam is blind with PRA and the sire has produced it. The dog must carry at least one gene for PRA and could carry both genes for it. This would be a poor choice even if our bitch was known to be clear of the defect because a large majority of the offspring, if not all, would carry the problem on into the future.

Sire #2

This dog has grandsires on both sides of the pedigree that have produced PRA-affected offspring. He is perhaps less at risk than sire #1, but let's try to do better.

Sire #3

Dam's side has no known PRA for three generations. On the sire's side, a grandsire has a sibling that produced PRA and a granddam with a sibling that carries it. This may be slightly less risky than sire #2 but still not the best.

Sire #4

Is an older dog whose eyes pass the CERF exam. He has sired well over 100 offspring and none of them have developed PRA even though they are old enough. No closely related dog is known to have PRA. This is by far the best choice for a stud.

However, it is not all that easy as clear eyes are only one of many comparisons that need to be made when planning a breeding. We must also look at what other inherited problems may be involved as well as what attributes we hope to gain from this breeding. Generation by generation, we must be alert for clues as to what recessives are being carried by our Basenjis. This is why accurate pedigrees are very important. Your pedigree is only as valuable as your knowledge of the genetic makeup of the dogs in it.

But, back to eliminating PRA. Let us say we have a very good quality bitch with PRA and can breed her to a sire thought to be clear of PRA. Will that solve our problem?

"Yes," said Dan, "because even though the offspring receive one gene for

PRA from the dam, they will also receive one normal gene from the sire, so the pups will not have PRA since it takes two affected genes to cause it."

"But," said Mary, "that is **not** eliminating the problem, that is only burying it. Every pup in that litter still carries one recessive gene for PRA, which it can pass on to future offspring and, somewhere down the road, it will meet a like PRA gene and produce PRA all over again. You are just burying the gene in your gene pool, not eliminating it!"

"Mary is right. But with no test for carriers available at this time, how do you eliminate it from your gene pool?", asked Ken.

Well, first you have to know where it is in order to get away from it. Starting with animals that you feel may not carry the PRA gene, line breed closely and watch the offspring. If it shows up, you know both parents are carriers. If it doesn't, try other crosses to related animals. The closer you can breed without seeing a recessive trait, the better the chances are that you have eliminate it. This may seem like an impossible task, but you do not have to do all the breedings yourself. You can learn a lot by looking at breedings of related animals that others have done and learn from them. If breeders work together and are truthful with each other about the results, there is much to learn by applying the rules of genetics. The more you know about an extended family of dogs, the clearer the picture you will have of what genes are in the gene pool and which dogs carry what. By breeding close, you will not only find the problems you wish to eliminate but you help to 'fix' the traits you wish to preserve and perpetuate.

By **selecting** breeding stock that is free from disease and that shows the attributes you desire, you can move the breed ahead. You must cull from breeding those animals that can perpetuate unwanted genes. The first rule of breeding should be, "**Do no harm!**"

Short-sighted breeders who cover up their problems by outcrossing do not have problems in their immediate litter. They are burying the problems deeper in their gene pools to spring forth later on some unsuspecting future breeder who has purchased stock from them. This practice may get today's breeder off the hook temporarily but can do much damage to the health and welfare of the breed in the long run.

Another example of a recessive that can lie buried for a long time is the blue eye. I see that woke you up! Yes, there is a recessive blue eye in Basenjis. The furthest back I can trace it is to an ancestor behind the dominant blacks. This was a red bitch who produced it when bred to her son. It also showed up in other dogs when she appeared on both sides of the pedigree. It was very rare and usually only one eye was blue, although I had a red puppy with two blue eyes. This blue was not china blue, nor like any blue eye I have seen in any other breed. It would have made Paul Newman jealous. The blue color was rich, clear, bright and intense. My blue-eyed puppy was beautiful and I regretted that I didn't have room to keep her at the time. She was sold to a pet home and spayed. Apparently this recessive has been bred out of the line that I am dealing

with, as I have not seen it again in my dogs. I did not hear of the blue eye again for about 20+ years, but recently it surfaced again and I am hearing of it in several places, including from a breeding of pure Africans (the recent imports).

I've also heard of a Basenji litter which included several puppies with what was described as china blue eyes (an all American breeding). If this description is accurate, this is something different from the blue eyes I have seen. China eyes are usually associated with breeds with merle in their gene pool and appear to have a lighter and darker flecked or spotted distribution of melanin deposits upon a blue iris background. This is as opposed to the very clear dark blue of the eye described earlier. Recessive traits like these can lie hidden for many generations before making themselves known.

"WOW!", exclaimed James, "I just figured something out! You said earlier something about needing to have two genes for the tan markings, P^{tp}, in order to have the correct clear tris. When you do this, at the same time you eliminate the chance of getting other unwanted genes like saddling, shading, etc. So you are really killing two birds with one stone, right?"

"Very good, James, you are starting to think genetically."

"What about brindles? They are a relatively new addition to the breed gene pool. How do we know whether or not they carry two genes for the tan markings?", asked Robin.

We don't know! We need to watch future breedings in order to learn this. A red that is produced from a brindle breeding may have only one gene for the tan markings. If this red is tri-factored and is bred to a tri, the tri offspring may be either clear or 'Fula' factored. If one is 'Fula' factored, then a tan marking gene was missing in the brindle and something else took its place.

If a pure-for-red produced by a brindle carries only one or no genes for tan markings, you will have to breed to a tri for two generations to determine if the tan marking genes were present in the brindle. In this second generation, if you get a 'Fula' tri, you will know that the brindle was lacking at least one of the tan marking genes.

"And if there is an absence of the tan marking in a brindle, this can recreate the 'Fula' factor even if 'Fula' was not in the pedigree anywhere, right?", questioned Joan.

"Yes, that is right."

"Then," Joan continued, "if a saddling gene replaced the tan marking gene, future offspring could have saddles."

Mary added, "It seems to me that having both brindle and black and tan in the same breed can really complicate things."

"Perhaps that is why most breeds discourage it. If you check the color requirements for all AKC breeds, you will find that the large majority will have one color pattern as desirable and the other listed as a fault. Even breeds that list color as immaterial usually do not have both patterns in their gene pool. For example, have you ever seen a black and tan whippet?"

Chapter 12

THE MORE YOU KNOW

When I was a small child, I loved to play in my grandmother's attic. Many fascinating things from the past had accumulated there. My great aunt was an artist, a good one. She had her own art show in New York City in the very early 1900's. Her medium was oils. At this time, she was very old and crippled up with arthritis and her painting equipment was stored in grandmother's attic. These things I was forbidden to touch.

Curious minds want to know. I found an old palette with dried paint smeared in swirls of colors that changed in shades and hues. I can do that! The old tubes of oil paint were drying up, but I managed to squeeze some of the basic colors out onto the palette. I selected a brush and began to 'mix' my paints.

I watched the red and yellow streak together in stripes and, with a little more mixing, it became shades of orange. I added some blue and repeated the procedure. Boy, what fun! I tried some other colors. In my childish mind, I thought that if a little was good, a lot would be better. I kept adding and mixing, but something went wrong. The pretty clear colors had disappeared, the striking intermediate colors were gone, and all I had was a muddy gray mess. At about that time, I heard my grandmother's footsteps on the stairs. There was no way I could separate the paints back to their original colors, much less squeeze them back into their tubes. I was in deep, deep do-do!

In later life, I chose another medium of expression for my artistic creations. But from my childhood experience, I had learned to be very careful about mixing colors.

Understanding genetics is a never-ending challenge. The more we learn, the more we realize how little we know! All the progress being made in the studies of DNA will be wasted on breeders who can not apply it to everyday life.

Hopefully this book will help you to see the little subtleties of nature that are all around us. Some day science will explain all the 'hows' and 'whys' of what is happening. In the meantime, let us not ignore the things we can see happening just because we can not explain them.

As an artist selects and mixes his paints on his palette, so can a breeder

select the genes to make up the portrait he wishes to create. If breeding ever becomes a science, it will no longer be an art. Let us enjoy the challenge of breeding better dogs by using our knowledge gained from experience, our intelligence to select wisely, and our gut instinct to guide us toward perfection. These are the things of which great breeders are made.

Class dismissed.

BRAIN-TWISTERS

For those adventurous people still wanting more . . .

Problem #1

You have a 'Fula' tri-brindle bitch. From her you wish to produce Basenji offspring of the four correct colors that do not carry any unwanted color genes.

How would you go about this task?

What kind of sires would you need?

Assuming that you got the color and gene combinations that you wanted in the first litter, how many generations would you have to breed to get each correct color? Just remember, if you can't tell for sure what an animal carries recessively, you will have to test breed it until you are sure.

How many litters would you have to breed to get each correct color?

If you got only one of each possible gene combination in each litter, how many useless puppies would you be stuck with?

Problem #2

You have a Basenji bitch of a color which has no name in Basenji terminology. It looks like a pinkish Weimaraner and it has blue eyes. From her you want to product Basenji offspring of the four correct colors that do not carry any unwanted color genes. Answer the questions asked in Problem #1.

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TEST ANSWERS

Section A

1. Pure-for-red, tri-factored red and tri colors.
2. Black and tri-factored red.
3. Brindle and red. (What they carry recessively will have to be proven in future breedings unless the reds show the mark of being tri-factored. This could possibly be seen in brindles, but there will always be a doubt without test breedings.)
4. Black and tri-factored red and pure-for-red.
5. Black, pure-for-red, tri-factored red and tri.
6. Brindle (two genes for red) and pure-for-red.
7. Brindle, pure-for-red and tri-factored red. (The brindle's recessives will be questionable.)
8. All pure-for-red.
9. Black, pure-for-red, tri-factored red and tri. (The black can carry any of the following combinations of recessives: pure-for-red, tri/tri, or red and tri. All puppies that receive the black gene from both parents will produce only black offspring in the first generation regardless of what they are mated with. You would have to test breed at least two generations with known qualities to determine what these dogs carry recessively.)
10. Black and pure-for-red.

Section B

1. Pure-for-red, tri-factored red. Possibly tri, 'Fula' tri, saddled or worse depending on the unknown recessive.
2. Black and red. One recessive in each pup would be red, the other would be either tri or 'Fula' black.
3. Brindle and tri-factored red. Brindles would carry one gene for red and one gene for tri at the "A" locus.
4. Black, brindle, pure-for-red, tri-factored red, 'Fula' black-factored red, saddled, blanketed or shaded reds, 'Fula' tri, tri-brindle and, God help us, 'Fula' tri-brindle. The black and brindle could carry most anything to confuse our breeding programs for many generations.
5. Brindle with "A" series unknown, tri-brindle, 'Fula' tri-brindle, pure-for-red, tri-factored red, tri, 'Fula' tri, 'Fula' tri-factored red, saddled, blanketed or shaded red.
6. Tri.
7. Tri and 'Fula' tri.
8. Brindle, pure-for-red, and tri-factored red. (Brindles could carry two genes for red or red/tri at the "A" series locus.)
9. Tri, 'Fula' tri, and 'Fula' black.
10. Tri-factored red, 'Fula' factored red, 'Fula' black, 'Fula' tri, and saddled, blanketed, or shaded reds.

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What are you looking back here for?
Do you expect me to give you ALL the answers?